US010767864B2

(12) **United States Patent**
Clegg et al.

(10) **Patent No.: US 10,767,864 B2**
(45) **Date of Patent: Sep. 8, 2020**

(54) **TURBINE COOLED COOLING AIR BY TUBULAR ARRANGEMENT**

(71) Applicants: **Rolls-Royce Corporation**, Indianapolis, IN (US); **Rolls-Royce PLC**, London (GB)

(72) Inventors: **Joseph Clegg**, Seymour, IN (US); **Robert A. Hicks**, Derby (GB)

(73) Assignees: **ROLLS-ROYCE PLC** (GB); **ROLLS-ROYCE CORPORATION**, Indianapolis, IN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 704 days.

(21) Appl. No.: **15/185,431**

(22) Filed: **Jun. 17, 2016**

(65) **Prior Publication Data**

US 2016/0370010 A1 Dec. 22, 2016

Related U.S. Application Data

(60) Provisional application No. 62/181,836, filed on Jun. 19, 2015.

(51) **Int. Cl.**
F23R 3/04 (2006.01)
F23R 3/00 (2006.01)
F23R 3/60 (2006.01)

(52) **U.S. Cl.**
CPC ***F23R 3/04*** (2013.01); ***F23R 3/002*** (2013.01); ***F23R 3/045*** (2013.01); ***F23R 3/60*** (2013.01); *F23R 2900/00005* (2013.01)

(58) **Field of Classification Search**
CPC .. F23R 3/04; F23R 3/002; F23R 3/045; F23R 3/60; F23R 3/00
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,454,711 A * 6/1984 Ben-Porat F23R 3/10
60/748
7,631,502 B2 12/2009 Burd et al.
(Continued)

FOREIGN PATENT DOCUMENTS

EP 1074792 A1 2/2001
EP 2546574 A2 1/2013
(Continued)

OTHER PUBLICATIONS

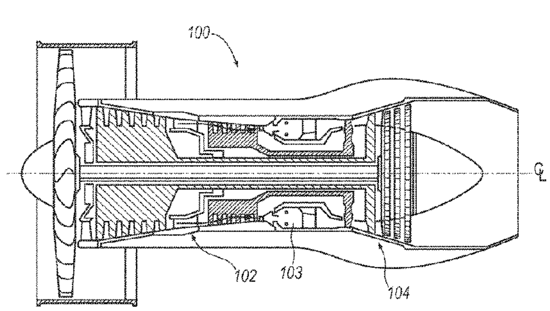
European Search Report dated Nov. 24, 2016 issued on EP Patent Application No. 16174173.1.

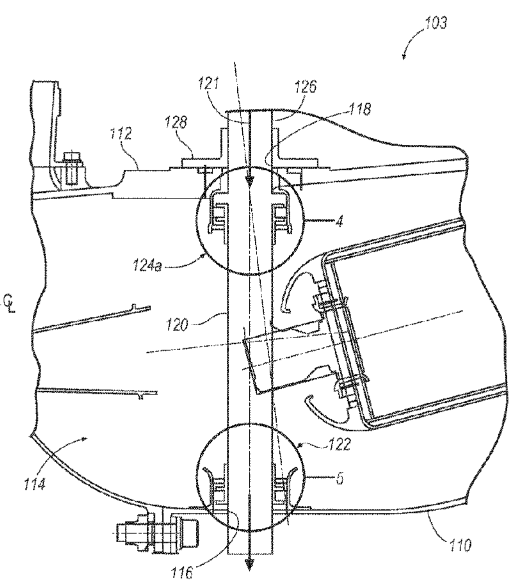
Primary Examiner — Craig Kim
(74) *Attorney, Agent, or Firm* — Fishman Stewart PLLC

(57) **ABSTRACT**

A gas turbine engine may include a combustor having an inner wall and an outer wall defining a combustion chamber there between. The inner wall and the outer wall may each have at least one opening into the combustion chamber. The gas turbine engine may also include at least one mobile conduit through which a cooling fluid may flow. The mobile conduit may pass through the combustion chamber from the at least one opening in the outer wall to the at least one opening in the inner wall. The gas turbine engine may further include a first joint and a second joint fluidly connecting the mobile conduit to the at least one opening in the inner wall and the at least one opening in the outer wall, respectively. The first joint and the second joint may enable multiple degrees of freedom of the mobile conduit within the combustion chamber.

20 Claims, 6 Drawing Sheets





(56) **References Cited**

U.S. PATENT DOCUMENTS

7,823,389	B2	11/2010	Seitzer et al.	
8,359,866	B2	1/2013	Dierberger et al.	
8,616,004	B2	12/2013	Zupanc et al.	
9,335,051	B2 *	5/2016	Jarmon	F23R 3/16
2005/0016182	A1	1/2005	Morenko	
2008/0112798	A1	5/2008	Seitzer et al.	
2010/0122537	A1 *	5/2010	Yankowich	F23R 3/005 60/754
2011/0023495	A1	2/2011	Bronson et al.	
2011/0088405	A1	4/2011	Turco	
2011/0185739	A1	8/2011	Bronson et al.	
2013/0129920	A1	5/2013	Dai et al.	
2014/0150436	A1	6/2014	Eroglu et al.	
2014/0216042	A1	8/2014	Hanson	
2014/0338347	A1	11/2014	Gage et al.	

FOREIGN PATENT DOCUMENTS

GB	588847	A	6/1947
GB	2474567	A	4/2011

* cited by examiner

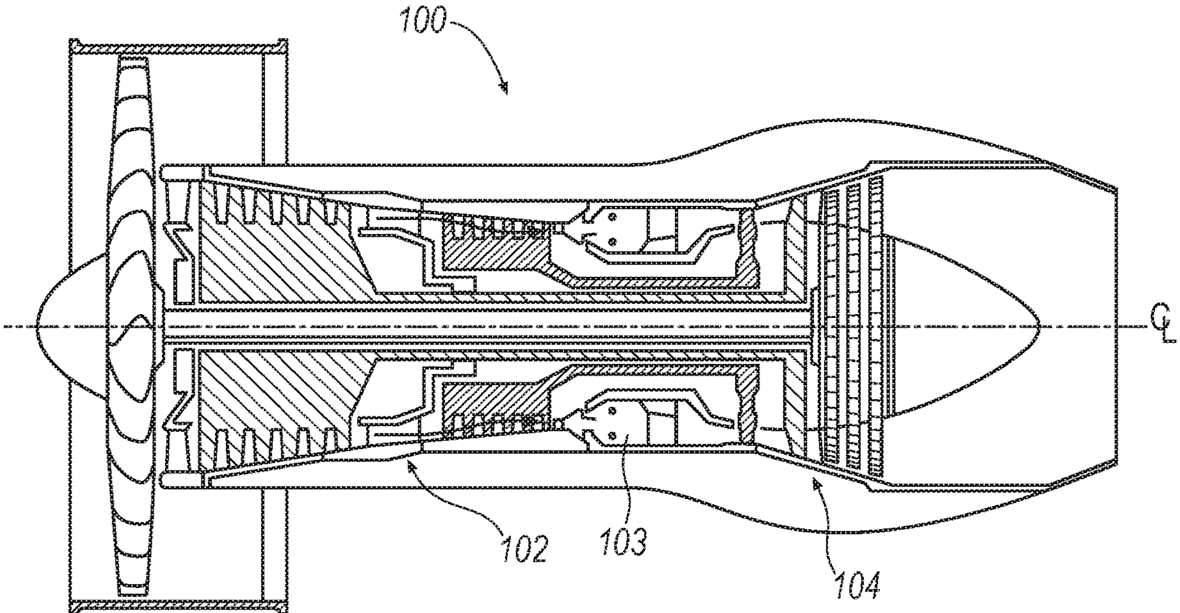


FIG. 1

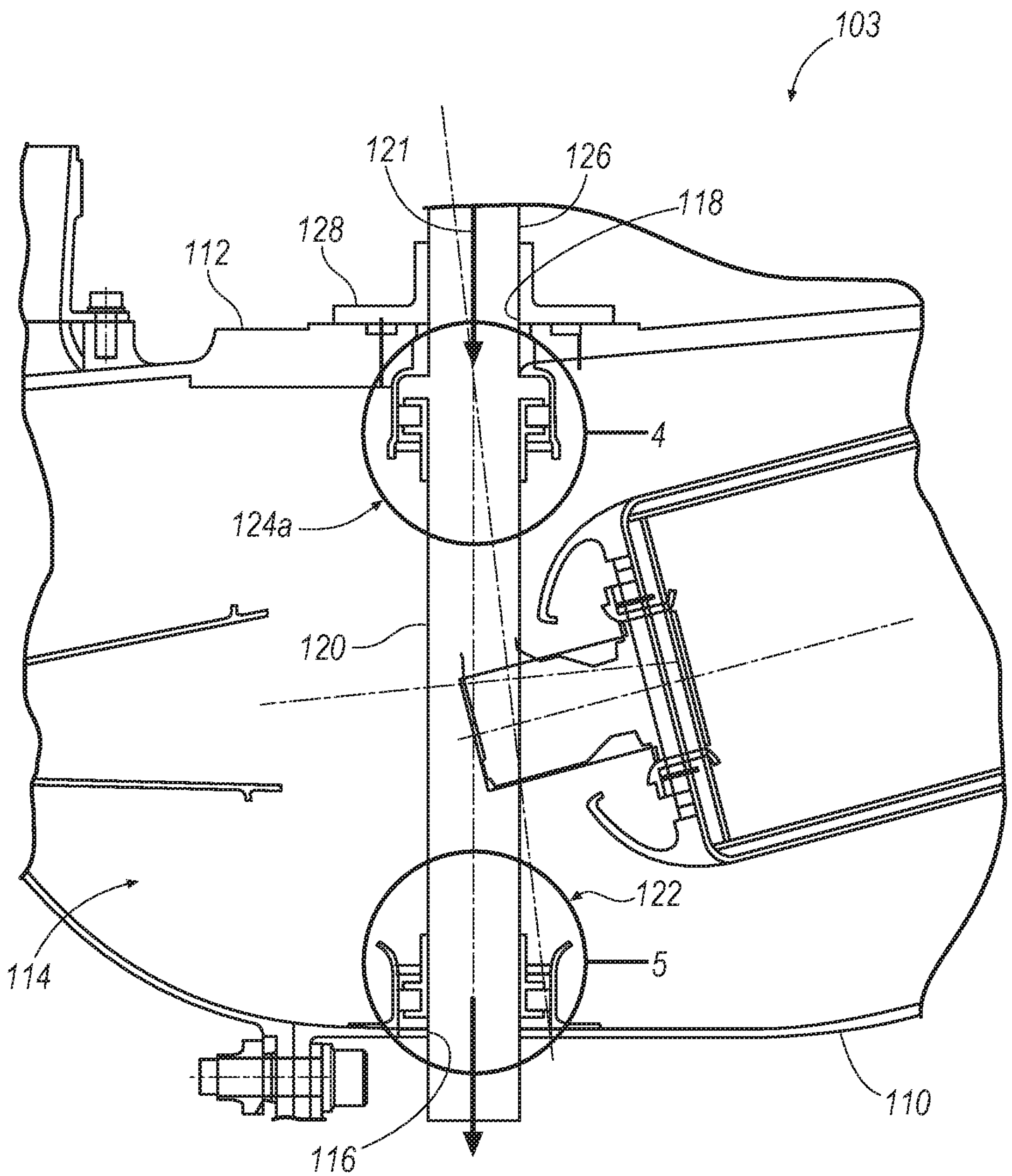


FIG. 2

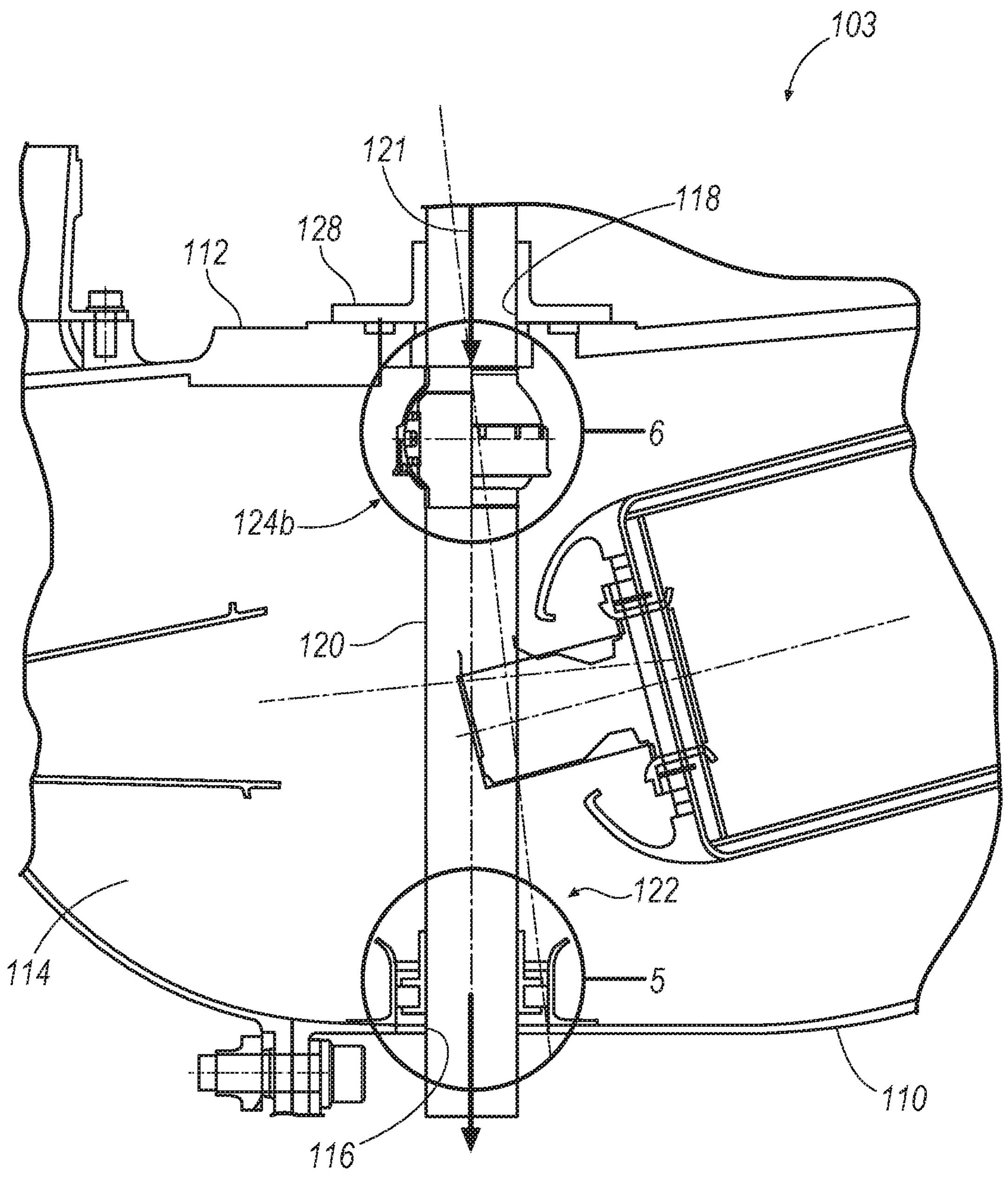


FIG. 3

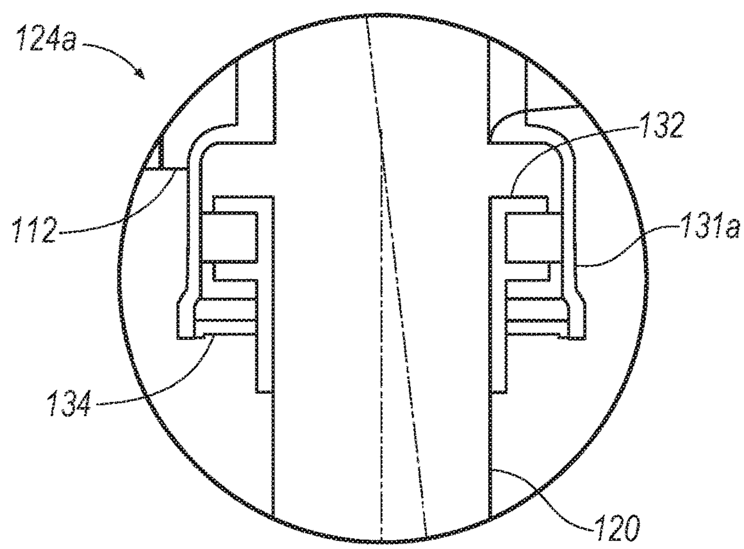


FIG. 4

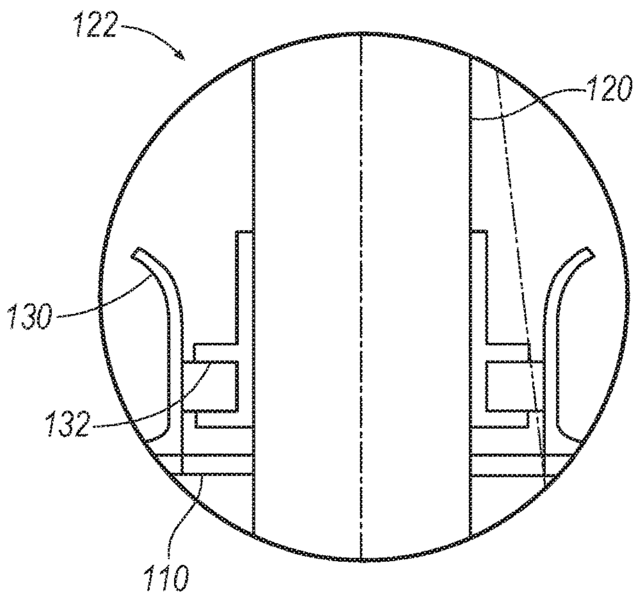


FIG. 5

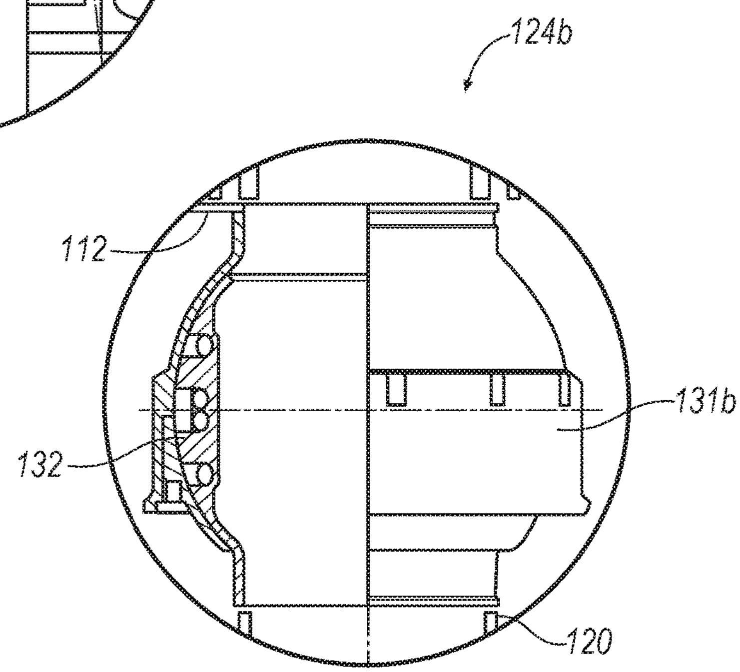


FIG. 6

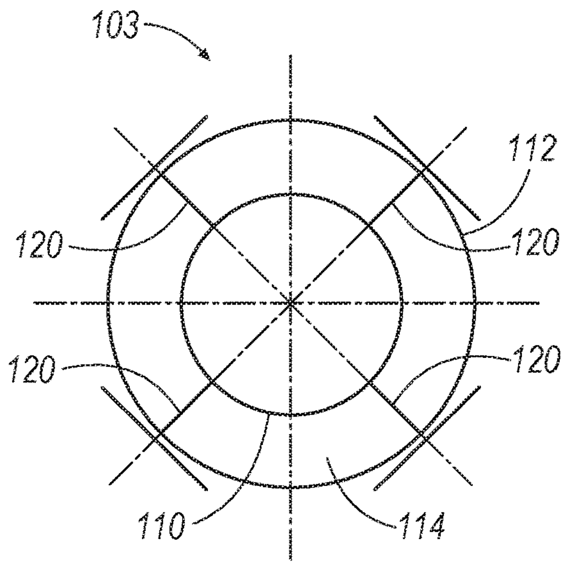


FIG. 7

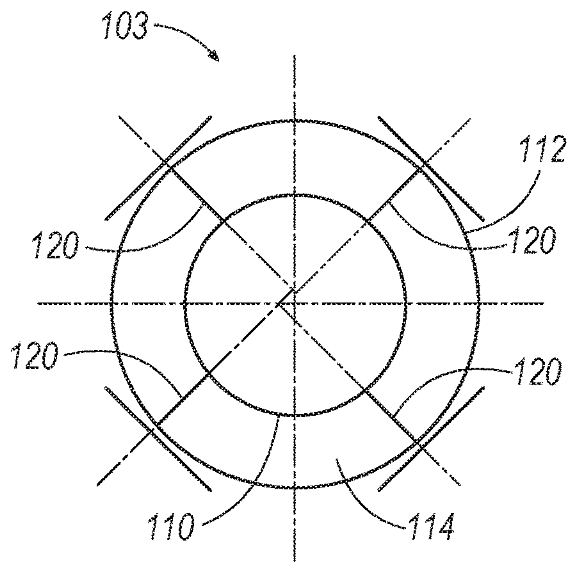


FIG. 8

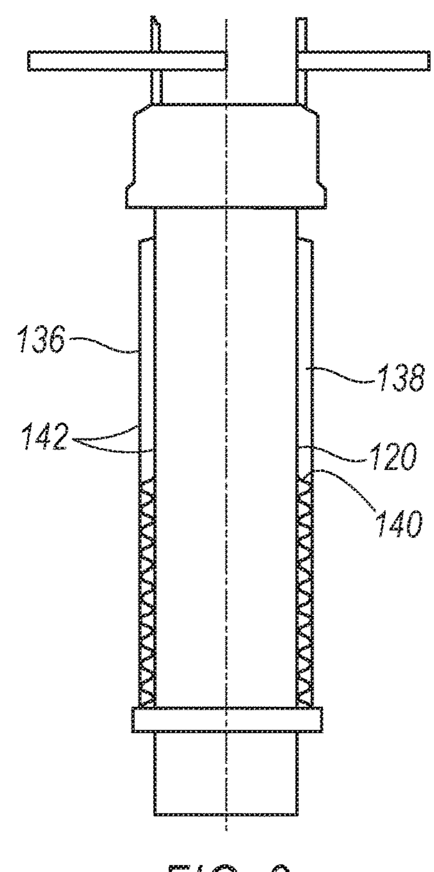


FIG. 9

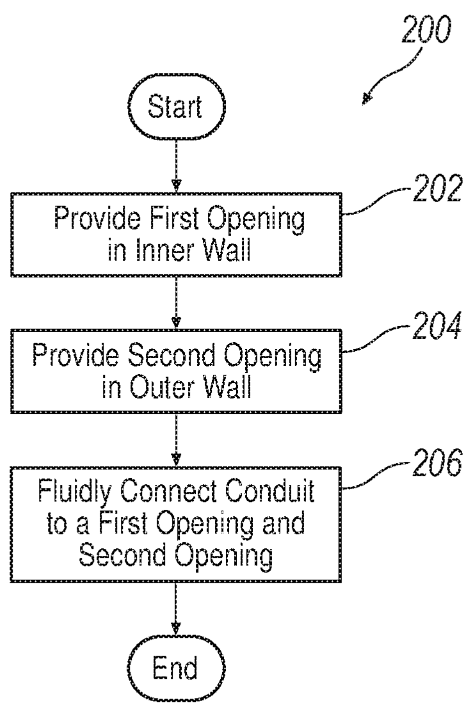

200
Start
Provide First Opening in Inner Wall
202
Provide Second Opening in Outer Wall
204
Fluidly Connect Conduit to a First Opening and Second Opening
206
End

FIG. 10

TURBINE COOLED COOLING AIR BY TUBULAR ARRANGEMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a non-provisional application claiming priority to U.S. Provisional Application No. 62/181,836 filed Jun. 19, 2015, which is hereby incorporated by reference in its entirety.

FIELD OF TECHNOLOGY

The present disclosure relates to a gas turbine engine implementing a tubular arrangement in a combustor for turbine cooled cooling air.

BACKGROUND

A gas turbine engine generally includes a compressor section, a combustor or combustor section, and a turbine section. The compressor section receives and compresses a flow of intake air. The compressed air then enters the combustor section in which a steady stream of fuel is injected, mixed with the compressed air, and ignited, resulting in high energy combustion gas, which is then directed to the turbine section. Some gas turbine engines may also include a source for providing a cooling fluid, such as air, within the engine, for example upstream of the turbine section and/or downstream of the compressor section. The cooling fluid may be circulated through the engine and a heat exchanger via a tube or conduit, which may be routed through the combustor.

The combustor generally includes an inner wall and an outer wall defining a combustion chamber there between, where the inner wall and the outer wall have different thicknesses for structural and pressure containment purposes. The compressed air discharged from the compressor section typically is at high temperatures, and therefore heats the combustor walls as it is introduced into the combustor. However, because of the different thicknesses, the inner wall and the outer wall may thermally grow at different rates. This, in turn, may affect or limit the implementation of any structures that interface with the walls, such as a tube or conduit within the combustion chamber that are through which the cooling fluid flows.

As such, there exists a need for a gas turbine engine that accounts for the differential thermal growth between the inner wall and the outer wall of the combustor. In particular, there exists a need for a gas turbine engine implementing a tubular arrangement for providing turbine cooling air such that the tubular arrangement may be provided in the combustion chamber and accommodates the differential thermal growth between the inner wall and the outer wall of the combustor.

BRIEF DESCRIPTION OF THE DRAWINGS

While the claims are not limited to a specific illustration, an appreciation of the various aspects is best gained through a discussion of various examples thereof. Referring now to the drawings, exemplary illustrations are shown in detail. Although the drawings represent the illustrations, the drawings are not necessarily to scale and certain features may be exaggerated to better illustrate and explain an innovative aspect of an example. Further, the exemplary illustrations described herein are not intended to be exhaustive or otherwise limiting or restricted to the precise form and configuration shown in the drawings and disclosed in the following detailed description. Exemplary illustrations are described in detail by referring to the drawings as follows:

FIG. **1** illustrates a schematic view of an exemplary gas turbine engine employing the improvements discussed herein;

FIGS. **2** and **3** illustrate schematic partial, cross-sectional views of a combustor of the gas turbine engine of FIG. **1** with a mobile conduit installed therein according to different exemplary approaches;

FIG. **4** illustrate an enlarged view of an upper floating joint at an outer wall of the combustor as implemented in the exemplary approach illustrated in FIG. **2**;

FIG. **5** illustrates an enlarged view of a lower floating joint at an inner wall of the combustor as implemented in the exemplary approaches illustrated in FIGS. **2** and **3**;

FIG. **6** illustrates an enlarged view of an upper gimbal joint at an outer wall of the combustor as implemented in the exemplary approach illustrated in FIG. **3**;

FIGS. **7** and **8** illustrate schematic diagrams of an alignment of multiple conduits according to different exemplary approaches;

FIG. **9** illustrates a schematic view of the mobile conduit with a double wall to accommodate an insulation feature of FIGS. **2** and **3**; and

FIG. **10** illustrates an exemplary method for implementing the exemplary approaches illustrated in FIGS. **2** and **3**.

DETAILED DESCRIPTION

A gas turbine engine generally may circulate a cooling fluid, such as air, from the engine to a heat exchanger. An exemplary gas turbine engine may include at least one mobile conduit through which the cooling fluid may flow and that may be positioned in a combustor of the gas turbine engine. The combustor generally may include an inner wall and an outer wall defining a combustion chamber there between, and the inner wall and the outer wall may each have at least one opening into the combustion chamber. The gas turbine engine may have a first joint and a second joint that fluidly connect the at least one mobile conduit to the at least one opening in the inner wall and the at least one opening in the outer wall, respectively, such that the cooling fluid may flow from the opening in the outer wall to the opening in the inner wall through the at least one mobile conduit. The first joint and the second joint may enable multiple degrees of freedom of the at least one mobile conduit within the combustion chamber, for example, to account for different rates of expansion of the inner wall and the outer wall. The first joint and/or the second joint may be floating joints that allow for multiple angular degrees of freedom and a translational degree of freedom of respective ends of the at least one mobile conduit. Alternatively, the second joint may be a gimbal joint that allows for multiple angular degrees of freedom with no translational degree of freedom of a respective end of the at least one mobile conduit.

An exemplary method for implementing a conduit in the gas turbine engine as described above may include first providing a first opening in the inner wall of the combustor, and providing a second opening in the outer wall of the combustor. The method may then include fluidly connecting the conduit to the first opening via a first joint and to the second opening via the second joint such that the cooling fluid may flow through the conduit from the second opening to the first opening. As explained above, the first joint and the second joint may enable multiple degrees of freedom of the conduit within the combustion chamber.

Referring to the figures, an exemplary gas turbine engine **100** is shown in FIG. **1**. The gas turbine engine **100** generally may include a **102**, a combustor or combustor section **103**, and a turbine section **104**. While the gas turbine engine **100** is depicted in FIG. **1** as a multi-shaft configuration, it should be appreciated that the gas turbine engine **100** may be a single-shaft configuration as well. In addition, while the gas turbine engine **100** is depicted as a turbofan, it should further be appreciated that it may be, but is not limited to, a turbofan, a turboshaft, or a turboprop. The compressor section **102** may be configured to receive and compress an inlet air stream. The compressed air may then be mixed with a steady stream of fuel and ignited in the combustor **103**. The resulting combustion gas may then enter the turbine section **104** in which the combustion gas causes turbine blades to rotate and generate energy.

Referring to FIGS. **2** and **3**, a partial section of the combustor **103** is shown. The combustor **103** generally may include an inner wall **110** and an outer wall **112** defining a combustion chamber **114** there between, and the pressure vessel inner wall **110** generally may be thinner than the structural outer wall **112**. The difference in thickness may vary depending upon the construction of the combustor **103**. For example, the outer wall **112** may be a composite outer wall, thereby having a thickness closer to that of the inner wall **112** than if the outer wall **112** is a structural outer wall. The relative thickness of the outer wall **112** with respect to the inner wall **110** may determine which approach illustrated in FIG. **2** or FIG. **3** may be implemented, as described in more detail below. The inner wall **110** may have a first opening **116**, and the outer wall **112** may have a second opening **118** into the combustion chamber **114**. The gas turbine engine **100** may include a tube **126** through which a cooling fluid, as represented by arrow **121**, is routed to the combustion chamber. The tube **126** may penetrate at least a portion of the second opening **118**, and may be secured to the outer wall **112** via a flange or bracket **128**.

The gas turbine engine **100** may also include a conduit **120** located within the combustion chamber **114** between the first opening **116** and the second opening **118**. The conduit **120** may enable the cooling fluid **121** to flow from the second opening **118** to the first opening **116**. The gas turbine engine **100** may further include a first joint **122** and a second joint **124***a,b* that fluidly connect the conduit **120** to the first opening **116** and the second opening **118**, respectively, such that the cooling fluid **121** may flow from the second opening **118** through the conduit **120** to the first opening **116**. The joints **122** and **124***a,b* generally may allow for multiple degrees of freedom, including angular and translational, and may include, but are not limited to, floating joints and gimbal joints.

In one exemplary approach depicted in FIG. **2**, the first joint **122** and the second joint **124***a* may both be floating joints, as depicted in FIGS. **4** and **5** and described in more detail below, that enable multiple angular degrees of freedom and a translational degree of freedom of respective ends of the conduit **120**. This configuration may be implemented when the thickness of the outer wall **112** is much greater than the thickness of the inner wall **110**, for example, when the outer wall **112** is a structural outer wall, as explained above.

In another exemplary approach depicted in FIG. **3**, the first joint **122** may be a floating joint, as depicted in FIG. **5**, and the second joint **124***b* may be a gimbal joint attached to an end of conduit **120**, as depicted in FIG. **6**. The floating joint may again enable multiple angular degrees of freedom and a translational degree of freedom of the respective end of the conduit **120**, whereas the gimbal joint only enables angular degrees of freedom and no translational degree of freedom of the respective end of the conduit **120**. This configuration may be implemented when the thickness of the outer wall **112** is closer to that of the inner wall **110**, for example when the outer wall **112** is a composite outer wall, as explained above.

Referring to FIGS. **4**-**6**, the first joint **122** and the second joint **124***a,b* are shown in more detail, where FIGS. **4** and **5** depict the second joint **124***a* and the first joint **122**, respectively, as floating joints according to the configuration of FIG. **2**, and FIG. **6** depicts the second joint **124***b* as a gimbal joint according to the configuration of FIG. **3**. In each configuration, the first joint **122** may include a tubular case **130** extending radially from the inner wall **110** into the combustion chamber **114** and around the first opening **116**. The first joint **122** may also include a spring seal **132** attached to the conduit **120** and configured to engage with the tubular case **130** to prevent any air from exiting the combustion chamber **114** through the first opening **116**, as well as to control the translational movement of the conduit **120**.

The second joint **124***a,b* may also include a tubular case **131***a,b* extending radially from the outer wall **110** and a spring seal **132** attached to the conduit **120**. In the configuration depicted in FIGS. **2** and **4**, the tubular case **131***a* of the second joint **124***a*, which may be a floating joint in this configuration, may be attached to the flange **128** and to the tube **126**. The second joint **124***a* may also include a retaining ring **134** within the tubular case **131***a* and configured to engage with the spring seal **132** after a certain amount of translational movement of the conduit **120** to ensure that the conduit **120** and the second joint **124***a* do not become disengaged from each other. In the embodiment depicted in FIGS. **3** and **6**, the tubular case **131***b* of the second joint **124***b*, which may be a gimbal joint as explained above, may be attached to an end of the conduit **120** such that only the other end of the conduit **120** may have translational movement when the inner wall **110** and outer wall **112** experience growth at separate rates.

Referring back to FIGS. **2** and **3**, the conduit **120** may have different cross-sectional shapes, including but not limited to circular and oval. In addition, the conduit **120** may be a straight tube or have multiple bends. The shape and configuration of the conduit **120** may be dependent upon different factors, including, but not limited to, available space within the combustor **103**. Furthermore, the gas turbine engine **100** may include multiple conduits **120** arranged in a radial alignment with the outer wall **112**, as illustrated in FIG. **7**, or in a non-radial alignment with the outer wall **112**, as illustrated in FIG. **8**. While FIGS. **7** and **8** show four conduits **120** spaced equally around the circumference of the combustor **103**, it should be appreciated that the gas turbine engine **100** may include any number of conduits **120** spaced apart from each other at any radial distance.

Referring now to FIG. **9**, the gas turbine engine **100** may also include an outer sleeve **136** disposed around at least a portion of the conduit **120**. The outer sleeve **136** may be spaced apart from the conduit **120** such that there is an air gap **138** between the outer sleeve **136** and the conduit **120**. At least a portion of the air gap **138** may be filled with insulation **140**. Alternatively or additionally, the conduit **120** and/or the outer sleeve **140** may be coated with a thermal barrier **142**.

Referring now to FIG. **10**, an exemplary method **200** for implementing the approaches illustrated in FIGS. **2** and **3** is shown. Method **200** generally may begin at block **202** at which the openings **116** and **118** are provided in the inner wall **110** and the outer wall **112**, respectively, of the combustor **103**. The openings **116** and **118** may be provided such that the conduit **120**, installed at block **204**, has either a radial alignment with the outer wall **112**, as illustrated in FIG. **7**, or a non-radial alignment with the outer wall **112**, as illustrated in FIG. **8**. After block **202**, method **200** may then proceed to block **204** at which the conduit **120** may be fluidly connected to the first opening **116** and the second opening **118** via the first joint **122** and the second joint **124**. With respect to the first joint **122**, this may first include attaching or otherwise extending the tubular case **130** into the combustion chamber **114**, and attaching the spring seal **132** to an end of the conduit **120**. The conduit **120** with the spring seal **132** may then be inserted into the first opening **116** until the spring seal **132** and the tubular case **130** engage with each other. With respect to the second joint **124***a,b*, the spring seal **132** may be attached to an end of the conduit **120**, which then may be inserted into the tubular case **131***a,b* of the second joint **124***a,b*. When the joint **124***a* is a floating joint, a retaining ring **134** may then be provided to maintain the end of the conduit **120** within the tubular case **131***a*. When the joint **124***b* is a gimbal joint, the tubular case **131***b* may be attached to the end of the conduit **120** such that there is no translational degree of freedom of that end of the conduit **120**.

After block **204**, method **200** may end. Method **200** may be repeated as many times as there are conduits **120** installed, for example four conduits **120** as illustrated in FIGS. **7** and **8**.

In addition, method **200** may also include providing an outer sleeve **136** around at least a portion of the conduit **120**, providing insulation **140** in at least a portion of an air gap **138** between the outer sleeve **136** and the conduit **120**, and/or applying a thermal barrier **142** to at least a portion of the conduit **120** and/or the outer sleeve **136**.

With regard to the processes, systems, methods, heuristics, etc. described herein, it should be understood that, although the steps of such processes, etc. have been described as occurring according to a certain ordered sequence, such processes could be practiced with the described steps performed in an order other than the order described herein. It further should be understood that certain steps could be performed simultaneously, that other steps could be added, or that certain steps described herein could be omitted. In other words, the descriptions of processes herein are provided for the purpose of illustrating certain embodiments, and should in no way be construed so as to limit the claims

It will be appreciated that the aforementioned method and devices may be modified to have some components and steps removed, or may have additional components and steps added, all of which are deemed to be within the spirit of the present disclosure. Even though the present disclosure has been described in detail with reference to specific embodiments, it will be appreciated that the various modifications and changes can be made to these embodiments without departing from the scope of the present disclosure as set forth in the claims. The specification and the drawings are to be regarded as an illustrative thought instead of merely restrictive thought.

What is claimed is:

1. A gas turbine engine comprising:

a combustor having an inner wall and an outer wall defining a combustion chamber there between, the inner wall and the outer wall each having at least one opening into the combustion chamber;

at least one mobile conduit passing through the combustion chamber from the at least one opening in the outer wall to the at least one opening in the inner wall, a cooling fluid being flowable from the at least one opening in the outer wall through the at least one mobile conduit to the at least one opening in the inner wall; and

a first joint and a second joint fluidly connecting the at least one mobile conduit with the at least one opening in the inner wall and the at least one opening in the outer wall, respectively the first joint and the second joint enabling multiple degrees of freedom of the at least one mobile conduit within the combustion chamber;

wherein the at least one mobile conduit is solid along a length of the at least one mobile conduit from the first opening to the second opening.

2. The gas turbine engine of claim **1**, wherein the first joint and the second joint are floating joints enabling the at least one mobile conduit to slide with respect to both the openings in the inner wall and the outer wall.

3. The gas turbine engine of claim **1**, wherein the first joint is a floating joint, and the second joint is a gimbal joint attached to an end of the at least one mobile conduit at the outer wall such that an end of the mobile conduit at the inner wall is able to slide with respect to the at least one opening in the inner wall.

4. The gas turbine engine of claim **2**, wherein the first joint and the second joint each includes a tubular case extending from the inner wall and the outer wall, respectively, into the combustion chamber around the respective openings, and at least one spring loaded seal, and wherein one of the first joint and the second joint further includes a retaining ring within the tubular case to limit a translational degree of freedom of the mobile conduit.

5. The gas turbine engine of claim **3**, wherein the first joint and the second joint each includes a tubular case extending from the inner wall and the outer wall, respectively, into the combustion chamber around the respective openings, and at least one spring loaded seal.

6. The gas turbine engine of claim **1**, wherein the at least one mobile conduit includes four conduits arranged in one of a radial alignment with the outer wall and a non-radial alignment with the outer wall.

7. The gas turbine engine of claim **1**, further comprising an outer sleeve disposed around at least a portion of the at least one mobile conduit.

8. The gas turbine engine of claim **7**, wherein the outer sleeve is spaced apart from the at least one mobile conduit such that an air tight cavity is created there between.

9. The gas turbine engine of claim **8**, wherein at least a portion of the air tight cavity is filled with insulation.

10. The gas turbine engine of claim **7**, further comprising a thermal barrier coating on at least a portion of at least one of the at least one mobile conduit and the outer sleeve.

11. The gas turbine engine of claim **1**, further comprising a thermal barrier coating on at least a portion of the at least one mobile conduit.

12. A method comprising:

providing a first opening in an inner wall of a combustor of a gas turbine engine, and a second opening in an outer wall of the combustor, the outer wall and the inner wall defining a combustion chamber there between;

fluidly connecting the conduit in the combustion chamber to the first opening in the inner wall via a first joint and to the second opening in the outer wall via a second joint;

flowing a cooling fluid through the conduit from the second opening to the first opening;

wherein the first joint and the second joint enable multiple degrees of freedom of the conduit within the combustion chamber; and

wherein the first joint is a floating joint, and the second joint is one of a floating joint and a gimbal joint.

13. The method of claim **12**, wherein the first joint and the second joint are floating joints enabling the conduit to slide with respect to both the openings in the inner wall and the outer wall.

14. The method of claim **12**, wherein the first joint is a floating joint, and the second joint is a gimbal joint attached to an end of the conduit near the outer wall such that an end of the conduit near the inner wall is able to slide with respect to the opening in the inner wall.

15. The method of claim **12**, further comprising aligning the conduit with the outer wall in one of a radial alignment with the outer wall and a non-radial alignment with the outer wall.

16. A gas turbine engine comprising:

a combustor having an inner wall and an outer wall defining a combustion chamber there between, the inner wall and the outer wall each having at least one opening into the combustion chamber;

at least one mobile conduit, the at least one mobile conduit passing through the combustion chamber from the at least one opening in the outer wall to the at least one opening in the inner wall, a cooling fluid being flowable from the at least one opening in the outer wall through the at least one mobile conduit to the at least one opening in the inner wall during operation of the gas turbine engine;

a first joint fluidly connecting the at least one mobile conduit to the first opening; and

a second joint fluidly connecting the at least one mobile conduit to the second opening;

wherein the first joint is a floating joint, and the second joint is one of a floating joint and a gimbal joint attached to an end of the at least one mobile conduit near the outer wall, a floating joints enabling multiple angular degrees of freedom and a translational degree of freedom of a respective end of the at least one mobile conduit, and a gimbal joint enabling multiple angular degrees of freedom with no translational degree of freedom of a respective end of the at least one mobile conduit.

17. The gas turbine engine of claim **16**, wherein the second joint is a floating joint such that the respective ends of the at least one mobile conduit are able to slide with respect to the openings in the outer wall and the inner wall.

18. The gas turbine engine of claim **16**, wherein the second joint is a gimbal joint attached to an end of the at least one mobile conduit near the outer wall such that only an end of the at least one mobile conduit near the inner wall is able to slide with respect to the opening in the inner wall.

19. The gas turbine engine of claim **16**, wherein the first joint and the second joint each includes a tubular case extending from the inner wall and the outer wall, respectively, into the combustion chamber around the respective openings, and at least one spring loaded seal, and wherein one of the first joint and the second joint further includes a retaining ring within the tubular case to limit the translational degree of freedom of the mobile conduit.

20. The gas turbine engine of claim **4**, wherein the tubular case of the second joint is attached to the outer wall via a flange.

* * * * *